Astronaut Office Crew Consensus Report
Columbus and Alpha Magnetic Spectrometer (AMS) Payloads
Neutral Buoyancy Laboratory (NBL) Development Test

Executive Summary

This NBL test was devoted to the evaluation of EVA payload operations on the Columbus and the AMS. The Columbus portion of the test was devoted primarily to generic EVA installation of the two Columbus payloads manifested on Flight 1E. The AMS portion of the test evaluated AMS EVA contingencies and generic crew translation on and around the AMS hardware installed on a starboard truss segment 3 (S3) payload attachment site (PAS).

In addition to these two payload objectives, the test included a piggyback assessment of a 12A.1 Main Bus Switching Unit (MBSU) Flight Releasable Attachment Mechanism (FRAM) handhold configuration change relative to its impact to the External Stowage Platform 2 (ESP2) operations.

The following is a summary of the results of this test:

- The Columbus payload installation options tested, using the baseline Columbus External Payload Facility (EPF) FRAM positions and orientations, were all acceptable. The preferred option for installing the second payload, given the first payload was already installed, was to have the payload below the crewmember's body, with the body oriented perpendicular to the plane of the FRAM interface and with the crewmember's head oriented towards the FRAM's Square Grid Interface (SGI). FRAM contingency attachment options were also tested and found acceptable using of combination of Body Restraint Tether (BRT) and Articulating Portable Foot Restraint (APFR), including use with the Worksite Interface (WIF) Extender.

- The AMS contingency tasks for Power Video Grapple Fixture (PVGF) contingency release, connector panel access, capture bar contingency release, passive Umbilical Mating Assembly (UMA) bolt access, and crew translation were all acceptable. There were some labeling issues identified, some fit check items to be verified on the flight hardware, and connector clocking to be determined.

- The 12A.1 MBSU FRAM two aft handhold configuration evaluation showed that the port side handhold complicated but did not preclude gloved-hand and tool access to the port, aft pin. The starboard (stbd) side handhold, with an adjacent FRAM and Orbital Replacement Unit (ORU), precluded gloved-hand and tool access to the stbd, aft pin. The only alternative would be to temporarily remove and stow the adjacent FRAM and ORU to perform the contingency pin operations. Given this option, the change was approved for this particular flight. In the future, the FRAM baseline handrail configuration will be adhered to, unless some particular unforeseen situation warrants consideration for a change. The proposed change will require EVA approval based on thorough crew evaluation and concurrence with the change.

It should be noted that the crew has not operated a flight quality contingency pin as part of any fit check or flight hardware demonstration. Therefore, the crew strongly recommends that a flight or qualification unit pin demonstration be scheduled for the EVA Branch of the Astronaut Office to verify EVA operations of the pin.

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This test was conducted on November 12 through 15, 2002, using the following Astronaut Office crew test participants: Clayton C. Anderson, Timothy J. Creamer, Michael L. Gernhardt, Claude Nicollier, Carlos I. Noriega (12A.1 piggy-back evaluation only), and Rex J. Walheim.

The Columbus payload evaluation used the Columbus mockup in a stand-alone configuration, outfitted with its upper EPF structure to support the zenith and stbd-facing payloads. The payloads consisted of a generic maximum volume mounted on a medium fidelity active FRAM mockup, which attached to a low fidelity passive FRAM mockup mounted on each of the two EPF upper payload sites.

For the AMS portion of the test, a low fidelity AMS mockup was mounted to the S3 trainer in a stand-alone configuration. The AMS mockup included the keel and capture latch interface to the S3 common attach system (CAS) site. The AMS mockup also included the AMS connector panel with low fidelity connectors, a low fidelity passive UMA, a medium fidelity Power Data Grapple Fixture (PDGF) that simulated a PVGF, and the AMS handrails used to verify crew translation. S3 trainer WIFs and a simulated AMS WIF were used to verify crew APFR positioning to AMS worksites. The AMS WIF was simulated by using the NBL crew positioning device. To verify the PVGF worksites, a low fidelity Space Station Remote Manipulator System (SSRMS) Latching End Effector (LEE) was attached to the AMS PDGF.

The 12A.1 FRAM handhold evaluation was performed using the ESP2 trainer in its flight configuration (attached to the airlock trainer), with FRAM sites 2, 3 and 4 populated. FRAM site #2 contained the Video Stanchion Support Assembly (VSSA) and FRAM. FRAM site #3 was outfitted with a generic ORU volume represented by the Columbus EPF maximum payload volume mounted on a FRAM. FRAM site #4 was the MBSU and its FRAM. All FRAMs included both a passive and active half.

The crew was provided with the following mockup hardware: low and high fidelity APFRs, medium and low fidelity power tools, low and high fidelity socket extensions, low and high fidelity right angle drives, high fidelity body restraint tethers (BRT), a medium fidelity WIF Extender, and high fidelity tool boards.

The crew was outfitted with low fidelity Simplified Aid For EVA Rescue (SAFER) units, high fidelity crew safety and equipment tethers, and high fidelity modified mini-workstation (MWS) with the T-bar and swing arm.

The crew used the following evaluation ratings to assess the EVA hardware and tasks in this test:

Category	Description
ACCEPTABLE (A)	Design changes are not required, although recommendations may be included to improve hardware operations
UNACCEPTABLE 1 (U1)	Design changes are required. Re-testing is not required; however, drawing review and/or shirt-sleeve inspection of flight or high fidelity hardware is required to verify adequacy of design changes.
UNACCEPTABLE 2 (U2)	Design changes are required. Re-testing required to verify adequacy of design changes.
INCONCLUSIVE (I)	No crew consensus can be reached due to inadequate hardware fidelity, inappropriate test conditions or environment, or insufficient number of test subjects used. Re-testing will be required unless specified otherwise.

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1. Columbus Payload Installation		
a. Zenith-facing payload installation on the EPF, using the SSRMS, is **ACCEPTABLE** if the FRAM active and passive half alignment markings are provided as required by the FRAM Interface Definition Document (IDD), reference Boeing document D684-10822-01.	**A**	Only the zenith payload sites on the EPF were tested. The nadir sites would be identical to the zenith sites. The crew installed the zenith-facing payload first, and then installed the stbd-facing one, using three different options with the prime crewmember on the SSRMS. Installation of the zenith-facing payload was performed using the nominal FRAM EVA handling positioning (a vertical body position, with head to zenith and feet to nadir), using the two vertical handholds on either side of the FRAM SGI mechanism. Nominally FRAM installation is a single-person task; however, if the second person is available at the worksite, that crewmember can assist with the task. It should be noted that all directions used to describe orientations is with respect to station coordinates, and assuming the Columbus is installed in its flight configuration. The black alignment stripe markings on the FRAM active and passive half alignment pin and cup are a requirement for EVA operations.
b. Stbd-facing payload installation on the EPF is **ACCEPTABLE** using Option 1.	**A**	Option 1 assumed a crew body positioning where the crew member is above the payload in a horizontal orientation, with the body parallel to the zenith side of the payload, head towards port and feet towards stbd.

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1. Columbus Payload Installation - Continued		
c. Clearance between the crewmember's helmet and the adjacent payload (zenith-facing) outer-most volume is **ACCEPTABLE** using Option 1.	**A**	In this option, the crew was able to maintain at least 4.5" clearance between the top of the helmet and the zenith-facing payload volume. The exact clearance for a particular crewmember would be dependent on the exact body orientation, SSRMS joint angles/positioning, and crewmember's arm reach.
d. Stbd-facing payload installation on the EPF using Option 2 is **ACCEPTABLE**, if the second crew is available to assist with visual alignment and guidance instructions, using an APFR in Columbus mockup end cone WIF #06 or, if preferred, using free-float operations using available EPF handrails and/or zenith payload handholds.	**A**	Option 2 assumed a crew body position, where the crewmember was in a vertical orientation, above the payload, with head towards nadir and feet towards zenith. In this body position, the crewmember handling the payload does not have visual access to FRAM alignment visual cues and must depend on the second crewmember for assistance.
e. Stbd-facing payload installation on the EPF using Option 2 is **UNACCEPTABLE 1**, if the task is a single-person task. This is due to the lack of adequate visual access to FRAM interfaces and alignment cues, given the crew body positioning in this option.	**U1**	This option is not to be used if it is a single-person task.
f. Clearance between the crewmember's body and the adjacent payload (zenith-facing) outer-most volume is **ACCEPTABLE** using Option 2.	**A**	In this option, the crewmember was able to maintain a 1' to 1 ½' clearance to the adjacent payload. The exact clearance for a particular crewmember would be dependent on the exact body orientation and SSRMS joint angles/positioning.

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1. Columbus Payload Installation - Continued		
g. Stbd-facing payload installation on the EPF using Option 3 is **ACCEPTABLE,** with one crewmember on the SSRMS and the second crewmember on an APFR located on Columbus mockup WIF #6.	**A**	In this option, the prime crewmember was on the SSRMS and the second crewmember was in an APFR located on Columbus mockup WIF #6. The SSRMS-based crewmember would be required to perform a 90-deg. yaw rotation of the FRAM and payload during translation to the worksite, to use the fwd-facing FRAM handrails and present the aft-facing handrails to the second crewmember. In this option, the SSRMS-based crewmember would be in a vertical orientation, with head to stbd and feet to port. If the assisting crewmember finds the APFR positioning in WIF #6 outside the work envelope, the crew can use the station WIF Extender aid.
h. A 90-deg. yaw rotation of the FRAM and payload by the SSRMS-based crewmember is **ACCEPTABLE**, with a slow rotational motion.	**A**	If the individual payload mass exceeds the 800 lbs mass or center of gravity (c. g.) currently approved by the EVA AIT for the Flight 1E, the mass handling will require evaluation using the JSC Virtual Reality (VR) simulation facility.
i. Tool (power tool with 7/16" x 2" or 6" socket extension) access to secure and release the FRAM attachment drive bolt on the SGI is **ACCEPTABLE** for the SSRMS-based crewmember to both zenith payload sites.	**A**	
j. Out of the three options used to evaluate installation of the stbd-facing EPF payload, with the zenith payload in place, the crew order of preference for task performance is Option 1, Option 2 and Option 3.	**N/A**	Option 1 should be the nominal baseline method of payload installation. Option 2 and 3, should be reserved for special unique circumstances or situations.

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1. Columbus Payload Installation - Continued		
k. The EPF mounting plate for the passive FRAM on the zenith-facing (and nadir-facing) payload sites have a horizontal handrail on both the fwd and aft sides. It is unclear whether this handrail meets EVA gloved-hand clearance requirements. The mockup design did not accurately represent the design. Therefore, the placement and its compliance with EVA handrail glove clearance requirements is **INCONCLUSIVE** and needs to be verified on the flight design during EVA fit checks of the flight hardware.	**I**	It is recommended that a gloved-hand fit check be scheduled on the flight hardware when the EPF passive and active FRAM are integrated for flight fit checks. The gloved-hand clearance around the rail section should be checked, as well as the gloved-hand clearance between the FRAM side handrails and this handrail.
2. FRAM Contingency Pin/Bolt Access on the EPF Payloads Using the SSRMS		
a. Although not tested, FRAM aft contingency pin access using an SSRMS-based crewmember is **ACCEPTABLE**.	**A**	The primary objective of the two aft FRAM contingency pin access was to use the worse case access, i. e. a foot restraint or possibly the BRT. The SSRMS would provide optimal worksite positioning. It should be noted that for SSRMS access, the crew would require the power tool with a 7/16" x 2" or 6" socket extension or possibly the right angle drive for the zenith-facing payload. The clearance for a straight socket without the right angle drive will have to be fit checked on the flight hardware. The stbd-facing payload would require the power tool with 7/16" x 2" or 6" socket extension.

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2. FRAM Contingency Pin/Bolt Access on the EPF Payloads Using the SSRMS - Continued		
b. The two FRAM fwd contingency bolts were not tested, but given the access shown for the FRAM attachment bolt using the SSRMS, access to the two contingency bolts at both payload locations is **ACCEPTABLE**.	**A**	To access the two fwd contingency bolts, the crew would require the power tool and very likely the right angle drive with a 7/16" x 2" socket extension. This will have to be verified in crew training.

3. FRAM Aft Contingency Pin Access on the Zenith-Facing EPF Payload Location		
a. Crew worksite positioning to the aft side FRAM aft contingency pin on the zenith-facing payload is **ACCEPTABLE** using an APFR on Columbus mockup WIF #04 or the BRT on Columbus flight end cone handrail #0944 or flight cylinder handrail #0934, if it is installed.	**A**	
b. Gloved-hand and tool (power tool with a right angle drive and 7/16" x 2" or 6" socket extension) access to the aft side FRAM aft contingency pin on the zenith-facing payload is **ACCEPTABLE**.	**A**	
c. Crew worksite positioning to the fwd side FRAM aft contingency pin on the zenith-facing payload is **ACCEPTABLE** using the BRT on Columbus flight end cone handrail #0912 or flight cylinder handrail #0933, if it is installed.	**A**	

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3. FRAM Aft Contingency Pin Access on the Zenith-Facing EPF Payload Location - Continued		
d. Gloved-hand and tool (power tool with a right angle drive and 7/16" x 2" or 6" socket extension) access to the fwd side FRAM aft contingency pin on the zenith-facing payload is **ACCEPTABLE**.	**A**	
e. Tool (power tool with 7/16" x 6" socket extension) access to the two aft contingency pins on the zenith-facing payload is **INCONCLUSIVE** without performing a flight hardware to tool fit check for clearance. The mockup configuration and design tolerances are not accurate enough to draw conclusive results.	**I**	The crew recommends that a fit check of the flight hardware and tool clearance be performed to verify FRAM aft contingency pin access with the standard sockets on the zenith and nadir-facing EPF payload locations. The 2" and 6" socket with the right angle drive should also be verified during flight crew procedures development.

4. FRAM Aft Contingency Pin Access on the Stbd-Facing EPF Payload Location		
a. Crew worksite positioning to the aft side FRAM aft contingency pin on the stbd-facing payload is **ACCEPTABLE** using an APFR on Columbus mockup WIF #06 with or without the WIF Extender aid, depending on crewmember reach.	**A**	

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4. FRAM Aft Contingency Pin Access on the Stbd-Facing EPF Payload Location - Continued		
b. Gloved-hand and tool (power tool with or without a right angle drive and 7/16" x 2" or 6" socket extension) access to the aft side FRAM aft contingency pin on the stbd-facing payload is **ACCEPTABLE** using an APFR on Columbus mockup WIF #06 with or without the WIF Extender aid, depending on crewmember reach.	**A**	
c. Crew worksite positioning to the fwd side FRAM aft contingency pin on the stbd-facing payload is **ACCEPTABLE** using an APFR on Columbus mockup WIF #06 with the WIF Extender aid.	**A**	
d. Gloved-hand and tool (power tool with a right angle drive and 7/16" x 2" or 6" socket extension) access to the fwd side FRAM aft contingency pin on the stbd-facing payload is **ACCEPTABLE** using an APFR on Columbus mockup WIF #06 with the WIF Extender aid.	**A**	If necessary, the crewmember may have to free-float access to the contingency pin, using the EPF structure.

5. AMS Capture Bar Release		
a. APFR ingress into S3 WIF #24 is **ACCEPTABLE** using the UMA handhold and PAS structure.	**A**	
b. Worksite positioning to the capture bar release bolts is **ACCEPTABLE** using S3 WIF #24.	**A**	

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5. AMS Capture Bar Release - Continued		
c. Tool (power tool with 7/16" x 12" socket extension) access to the two capture bar release bolts #1 and #2 is **ACCEPTABLE**.	**A**	The task could be performed using the 18" extension, but the baseline should be the 12", with the 18" being a flight crew preference option.
d. The mockup EVA labeling of the bolts appeared acceptable during testing, relative to general location and content, but it was not the flight detail label design (relative to font and location). Therefore, flight EVA bolt labeling is **INCONCLUSIVE** until flight drawings have been reviewed and flight labeling has been verified on the flight hardware during fit checks.	**I**	Provide the EVA Branch of the Astronaut Office flight label drawings for review and schedule label inspections during flight hardware fit checks.
e. Gloved-hand access to release (pull the bar handle through the keel pin structure) and re-install is **ACCEPTABLE**.	**A**	During one of the runs, the handle and bar were completely released from its mounting supports. This was probably a mockup issue, as the flight design should have the bar captive. This should be verified.
f. The design of the bar handle is **ACCEPTABLE**.	**A**	It is recommended that the flight design be reviewed as part of the EVA flight hardware fit checks.
g. The instructional label on the bar handle appeared acceptable, however this was only the mockup design. Therefore, the flight EVA handle labeling is **INCONCLUSIVE** until the flight drawings have been reviewed and flight labeling has been verified on the flight hardware during fit checks.	**I**	Provide the EVA Branch of the Astronaut Office flight label drawings for review and schedule label inspections during flight hardware fit checks.

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5. AMS Capture Bar Release - Continued		
h. Since the mockup design of the capture bar mechanism was a low fidelity representation of the flight design, it was not possible to fully evaluate fit, tolerances and forces relative to the EVA interface. Therefore, the flight design is **INCONCLUSIVE** until a flight design fit check can be performed on the flight or qualification unit.	**I**	An EVA fit check should be scheduled with the participation of the EVA Branch of the Astronaut Office to operate the flight mechanism design. This can be performed on the flight or qualification unit.
i. The location of the two handrails on the AMS keel structure is **ACCEPTABLE** for crew translation and crew restraint/stabilizations aids during the capture bar release/re-install tasks.	**A**	

6. AMS Connector Panel		
a. APFR ingress into S3 WIF #15 is **ACCEPTABLE** using the UMA handhold and PAS structure.	**A**	
b. Worksite positioning to the AMS connector panel is **ACCEPTABLE** using S3 WIF #15.	**A**	

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6. AMS Connector Panel - Continued		
c. Gloved-hand access to each of the six connectors on the AMS connector panel is **ACCEPTABLE** with the zenith connectors having their bails oriented towards zenith and the nadir connectors having their bails oriented towards nadir.	**A**	
d. The AMS panel connector identification labels (jack or "J" numbers) should be located on the stbd side (side away from AMS keel) of each connector, and placed towards the outboard edge of the panel so that the cables and connector back-shells do not block crew visual access of the labels. The labels should be oriented with the tops of the lettering towards stbd.	**N/A**	The NBL labels used were acceptable relative to font size, although they were not the flight configuration. Therefore, it is recommended that the final label design drawings be provided to the EVA Branch of the Astronaut Office for review prior to flight label installation. This includes the cable connector identification labels. All EVA connector labels should meet EVA labeling requirements in Space Station Program (SSP 50005), Revision (Rev.) C.
e. Because there are other panels and connectors in the worksite, it is **UNACCEPTABLE 1** for the AMS panel not to have an identification label. This is inconsistent with EVA labeling requirements in SSP 50005, Rev. C.	**U1**	The hardware provider generally has its own panel identification scheme of alphanumeric characters that correlates to the wiring schematics for the electrical system. If not, there is one recommended in SSP 50005, however it is far too complicated for this application. Therefore, for simplicity, it is recommended that the panel be labeled as "AMS CONN PNL" or "AMS PNL 1" or "AMS PNL A".

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7. AMS Passive UMA		
a. APFR ingress into S3 WIF #11 is **ACCEPTABLE** using the UMA handhold and PAS structure.	**A**	This evaluation did not evaluate UMA changeout; it only assessed UMA attachment bolt access from S3 WIF #11.
b. Worksite positioning to the passive UMA is **ACCEPTABLE** using S3 WIF #11.	**A**	
c. Tool (power tool with the right angle drive and 7/16" x 2" or 6" socket extension) access to the four passive UMA attachment bolts is **ACCEPTABLE** using S3 WIF #11.	**A**	Depending on crewmember reach, some crewmembers can use the power tool without the right angle drive. The right angle drive should be baselined and during crew training the flight can determine what tool configuration will be used.

8. SSRMS Contingency Release From the AMS PVGF		
a. APFR ingress into the AMS WIF is **ACCEPTABLE**.	**A**	For testing purposes, the AMS WIF location was approximated using the NBL crew positioning device. During flight crew training this worksite will need to be verified.
b. Worksite access to the AMS PVGF is **ACCEPTABLE** using the AMS WIF.	**A**	
c. Tool (power tool and 7/16" x 6" socket extension or power tool with right angle drive and 7/16" x 2" socket extension) access to the PVGF grapple shaft release bolt is **ACCEPTABLE** using the AMS WIF.	**A**	
d. Tool (power tool and 7/16" x 6" socket extension or power tool with right angle drive and 7/16" x 2" socket extension) access to the LEE EVA drive is **ACCEPTABLE** using the AMS WIF.	**A**	Due to the simulated WIF location and potential tight tool clearances between the AMS structure and the LEE, especially with the power tool and the 6" extension, this access should be verified during flight crew training.

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9. AMS Crew Translation Paths		
a. Crew translation from the S3 truss and between the AMS and adjacent maximum payload volume is **ACCEPTABLE**.	**A**	The crewmember may require transition to the AMS keel handrails to avoid contact with the S3 Flight Releasable Grapple Fixture (FRGF).
b. Crew translation from the S3 truss to the AMS FRGF worksites, including transition between S3 to AMS, is **ACCEPTABLE**.	**A**	The crew will have to be careful and avoid contacting the no touch areas of the AMS during translation to the worksite
10. 12A.1 MBSU FRAM Two (Aft) Handrail Configuration Evaluation on ESP 2 FRAM Site #4 – Piggyback Objective		
a. Crew tool and gloved-hand access to the port, aft contingency pin is **ACCEPTABLE**. The crew will have to work to get a body position and orientation to allow access to the port pin. This includes both the tool and gloved-hand.	**A**	For this evaluation, the ESP 2 pallet was configured with the MBSU and its FRAM in FRAM site #4, large generic ORU volume (equivalent to the maximum Columbus FRAM payload volume) and FRAM in site #3, and the VSSA and FRAM in site #2.
b. Crew tool and gloved-hand access to the stbd, aft contingency pin is **UNACCEPTABLE 1** because of tight gloved-hand clearance below the MBSU stbd, aft FRAM handrail and tight clearances between the FRAMs sites 3 and 4.	**U1**	The only available option to access the stbd, aft FRAM contingency pin is to temporarily remove and stow the FRAM and ORU in site #3.
c. The EVA Branch of the Astronaut Office has never operated or fit checked a flight aft contingency pin on a flight quality FRAM. This is **UNACCEPTABLE 2**.	**U2**	The crew recommends that the EVA Branch of the Astronaut Office perform a fit check of a flight or qualification unit FRAM, to verify EVA aft pin operation.